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	1. Original project aims We investigate the hypothesis that selecting units of work to automate based on procedures for humans will improve human-automation designs. The structured actions sets within procedures, such as steps, can be used as the basis for meaningful, sharable organization of what is automated and how information should be passed between humans and automation. We hypothesize that human-automation interaction organized this way will provide several benefits, relative both to manual operations and to less user-centric automation, including effective execution and more adaptable use with flexible levels of automation. To test this hypothesis we will 1) develop strategies for using human procedures to identify units of work for adjustable automation, 2) build a test environment with software for manual or partially automated execution of procedures, and 3) use this environment to evaluate the effectiveness of alternative strategies for executing procedures.		

Task Description:	2. Key findings First, structured but informal piloting identified several improvements needed in the interaction design of the PRIDE procedure automation software. These improvements ensure that the formal pilot study can address the underlying human-system integration, without being defeated by poor design choice. Second, the pilot study is producing findings about human use and its measurement. Our performance metrics for this study are based on measuring correctness and timing when following a procedure. Our study of metrics revealed two types of correctness to be measured - human action and behavior of the human-automation system. Performance with respect to human action assesses how well a person follows the procedure; performance with respect to the human-automation system assesses if human operations, whether following the procedure or not, produce the desired system effects safely. Thus a key finding is the need for new performance measures to characterize the behavior of the human-automation system. We assessed what combination of document-based instruction and experience-based practice is needed to gain competence quickly in the study. Results from ongoing testing indicate that subjects can perform procedures using PRIDE manually (PRIDE-manual condition) without initial, structured instruction. The experimenter provided modest instruction on how components work during a run, if needed. Training is required for running procedures in the ISS condition. The formal pilot is assessing PRIDE operation and comparing its performance to an interface very similar to that used on ISS. The study also investigates use of PRIDE's partial automation modes. Human subject testing in the formal pilot study is in progress at the time of this report, and will yield additional findings once test data are analyzed. 3. Impact of key findings We assess how well task allocation strategies improve performance by comparing performance with partial automation to manual performance of procedures. We predict that human performance of procedures in the PRIDE-manual condition will be comparable to or better than human performance of the same procedures in the ISS condition. To test this hypothesis we added the ISS condition to the pilot study and are comparing performance for these two conditions. If this hypothesis is proven true, manual performance of procedures will be measured in Years 2 and 3 only using PRIDE-manual. Further, ongoing PRIDE development will be guided by improvements suggested when comparing these very different systems. New measures of performance were identified to assess the effectiveness of strategies for allocating tasks to automation. They also provide a means of assessing how well these strategies address safe use of procedures in complex dynamic environments, where degraded systems and novel use can result in procedure actions with unexpected effects. We predict that a shift from measuring how well a person follows procedure steps to measuring how well a person achieves desired system states safely will provide a more accurate and flexible measure of performance. A preliminary finding of the PRIDE evaluation is that the very ease of use of the PRIDE interface can mask the need for the user to pause and consider before taking action; this is especially important for actions with potential safety risks. The current PRIDE interface provides a minimum of information needed to send commands and observe command effects. We predict that displaying additional context information about intended system effects and potential risks of procedure actions will improve situation awareness when deciding whether to automate. 4. Proposed research plan for next year Year 2 research will evaluate the initial strategy for allocating tasks to automation around procedural units of work. Experiments will compare two task allocation strategies (manual vs partially automated) for their effect on performance accuracy and speed, and on how easily users generalize from one procedure to another. We predict improvement of partially automated over manual execution on these measures. We expect to modify and develop new procedures, software, and simulations for use in performing these evaluations. We will develop new measures of human performance that characterize how well human actions achieve the desired system states in procedures, and avoid unsafe states. We then will evaluate the hypothesis that a shift from defining error by measuring how well a person follows procedure steps to measuring how well the person achieves desired system states safely provides a more accurate and flexible measure of human performance with procedures. We will develop new procedures and PRIDE displays that provide context information about the intended effects and potential risks of procedure actions, and evaluate whether these displays improve situation awareness when deciding whether to automate.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	As crewed missions move deeper into space and communication latency increases, astronauts will be unable to depend on real-time support from flight controllers, such as performing or advising on procedures as done for the International Space Station (ISS). Astronauts will have a longer time lag between task training and execution while also needing to perform more, and more diverse, tasks. These can increase astronaut workload, decrease efficiency, and increase the risk of suboptimal task execution. A critical resource for meeting these challenges is greater reliance on spacecraft automation. Today astronauts and flight controllers carry out tasks by following written procedures. As a result approaches that integrate automation with procedures are a good fit to NASA's concept of operations. If human-automation integration (HAI) for such procedure automation is not appropriately designed, however, increased automation may contribute to rather than alleviate these challenges. The strategies for allocating tasks to automation resulting from this project is of direct benefit to current and future NASA human space exploration missions. There is significant recent interest in remote operations and automation for the oil and natural gas drilling, extraction, and processing. Similar to NASA, oil and gas drilling operations use Standard Operating Procedures (SOPs) that would benefit from procedure automation software like PRIDE. Whether monitoring and controlling an off-shore oil rig from an on-shore location using both local and remote experts or controlling robots that monitor and maintain off-shore rigs during an evacuation, or controlling robots that perform disaster response tasks in large refinery, the need for procedure-based automation in the oil and gas industry is growing. TRACLabs is currently participating in a field test of our PRIDE procedure automation technology with two oil and gas companies, and in discussion with multiple other companies about deploying our procedure automation technology into drilling operations. The improved support for human interaction with automation resulting from this project has direct application to the oil and gas drilling. The goal of developing strategies for automation that consider safety risks is particularly relevant to this industry. We also anticipate that task allocation strategies demonstrated effective for NASA and the oil and gas industry would have potential use for any industry operating in complex dynamic environments with a high cost of failure. Such industries include chemical and nuclear process control, power management and distribution, and military operations.

Task Progress:	Year 1 research aims to prepare for evaluating strategies to allocate tasks to the PRIDE procedure automation software in Years 2 and 3. We are developing software and conducting a pilot study to develop metrics and methods for these experiments and to evaluate PRIDE. Task progress is described below. Task 1: Define scenarios, task allocation strategies, and metrics for pilot study. Scenarios developed for the pilot include executing procedures to start up, change modes, and shutdown a simulation of the CO2 Removal System (CDRS). Initial strategies were developed for allocating tasks to automation according to units of work. Performance metrics were defined to measure the accuracy and timing in following procedures during the pilot. Additional metrics were identified but not implemented to characterize how well and how safely human actions achieve the desired system states implied by the procedure. Task 2: Develop software for pilot study. The PRIDE software was modified for the formal pilot study, including changes to improve ease of use and consistency of interaction. Software was developed to monitor and log to database the user's interaction with PRIDE. New procedures were developed to give the subjects more options for controlling the CDRS. New software was developed to emulate ISS displays and log user interactions with these displays to database. This software was integrated with the CDRS simulation for subjects to use to monitor and control the CDRS. PRIDE, ISS software, and the CDRS simulation were deployed at a website for early evaluation at ARC. Subsequently this software was installed on computers at ARC for the pilot. Task 3: Conduct formative evaluation of procedure software. A formative evaluation of PRIDE is being conducted at ARC in 2 phases. During the first informal phase, human subject tests were performed to develop a training approach, and to identify changes to PRIDE prior to experiments comparing it to the ISS. Six subjects were tested with the PRIDE software. During the second formal phase (now ongoing), human subject tests are being conducted to compare the PRIDE conditions (manual and partially automated) to the ISS condition. Data collection from an expected 12 subjects is in progress at the time of this report. Task 4: Analyze study results. Data from the first phase of the pilot study were analyzed. Data from the second phase of the pilot study is being collected. Metrics for accuracy and timing will be computed from these data. A preliminary analysis of these data will be done by the end of Year 1. Task 5: Begin software development for Year 2. Software development to author and execute malfunction procedures was begun, to enable evaluating a more diverse set of procedures in Year 2. Malfunction procedures are used to safe systems after an anomaly and diagnose the anomaly cause. Software development for automatic computation of metrics also was begun to prove out our approach for Year 2.
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